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GENERAL DYNAMICS | CONVAIR

Report No. 8926-166; 56 254

Material - Brazing Alloys - Titanium Alloy Joining

Wetability and Erosion Characteristics

L. D. Girton, H. C. Turner, W. M. Sutherland

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Abstract:

Brazing tests involving titanium honeycomb core (~~0.002" foil~~, 3/16" hexagonal core, 0.500" thick, welded, commercially pure titanium) joined to various titanium alloy face plates (~~commercially pure~~, Ti 5Al-2½ Sn, Ti 6Al-4V, nickel plated Ti 5Al-2½ Sn, nickel plated Ti 6Al-4V, and nickel plated Ti 8Mn) ranging 0.015" to 0.031" thickness with an eutectic composition silver-copper brazing alloy (Handy and Harman Co. BT alloy, 72% silver - 28% copper). Heating the BT alloy to its flow point (1435°F) in contact with the various titanium alloys and in the presence of an inert atmosphere showed that lithium additions to the brazing alloy and nickled plating on the titanium alloys was not necessary to achieve good flows and wetability. This was attributed to the ability of titanium to absorb its own oxide at temperatures above 1300°F, a situation in which titanium alloys appear to possess a certain "self-cleaning" capability in the presence of inert atmospheres and moderate oxide coatings. The erosion of titanium, especially the 0.002" thick honeycomb core material was attributed to its solution in the brazing alloy, a characteristic which requires use of minimum brazing time to obtain satisfactory joints.'

Reference: Girton, L. D., Turner, H. C., Sutherland, W. M., "Titanium Honeycomb Panel, Silver Brazed," General Dynamics/Convair, Report MP 56-254, San Diego, California, 3 December 1956. (Reference attached).

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A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

REPORT 56-254

DATE 12-3-56

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MRS 56-190

TITLE

REPORT NO. 56-254
TITANIUM HONEYCOMB PANEL
SILVER BRAZED

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PREPARED BY L. D. Girton
L. D. Girton

GROUP MATERIALS & PROCESSES LAB.

CHECKED BY H. C. Turner
H. C. Turner

REFERENCE

CHECKED BY W. M. Sutherland
W. M. Sutherland,
Group Engineer

APPROVED BY E. F. Strong
E. F. Strong
Chief, Engineering
Test Laboratories

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REVISIONS

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REPORT NO. 56-254
TITANIUM HONEYCOMB PANEL
SILVER BRAZED

INTRODUCTION:

Previous tests, T.N. 9194, 9194-2, 9240, using silver-base brazing alloys to join titanium have indicated short time at brazing temperature is necessary, otherwise excessive alloying and core erosion is the result. This fact precludes furnace brazing. In this investigation, therefore, rapid heating and cooling procedures were employed. Flowing argon gas provided the necessary protection from atmospheric oxidation.

OBJECT:

Phase I - To conduct wetability and filleting tests of silver brazing alloys on titanium core-skin specimens.

Phase II - To fabricate a silver brazed all-titanium honeycomb panel of suitable size for flexural testing.

CONCLUSIONS:

Phase I - As evaluated in this investigation the following conclusions may be made:

1. Wetabilities and flows of BT silver brazing alloys were satisfactory on all of the titanium core - titanium skin specimens. Lithium additions and nickel platings were apparently unnecessary.

2. A satisfactorily filleted joint was formed with negligible erosion of the titanium core by utilizing a short heating cycle.

3. Stainless steel core - titanium skin specimens evidenced negligible alloying or erosion of the stainless core for both the short and long heating cycles. Flow and filleting were satisfactory.

Phase II - A 3" x 8" titanium core - titanium skin silver-brazed honeycomb panel was fabricated and flexurally tested according to Convair ZM-397.

RECOMMENDATIONS:

At the present time stainless steel sandwich parts are produced by furnace brazing. Extensive fixturing and tooling is necessary to maintain the necessary flatness or contour. Theoretically it should be possible to fabricate all-titanium honeycomb by the same method if a brazing alloy can be developed which wets, forms a ductile joint and does not diffuse into the titanium excessively.

RECOMMENDATIONS, (Cont'd.)

The foregoing suggests two approaches for future experimentation:

1. Develop a brazing alloy which can be used to fabricate all-titanium honeycomb components by furnace brazing.

2. Use silver based brazing alloys and investigate the commercial possibilities of combining fixturing and short brazing time - as was done to fabricate a test specimen in this report - for the production of parts.

   If this appears to be feasible, determine time-temperature-diffusion relationships (T-T-D Curve). From these data specifications can be compiled necessary for the design of the heating fixture. It is suggested the type of specimen and procedures used in Phase I of this study be employed, except that heating be accomplished with a salt bath.

PHASE I
MATERIALS AND TEST PROCEDURES:

The main prupose of this phase was to ascertain if Lithium additions to a silver based brazing alloy enhanced its wetability characteristics on bare and nickel plated titanium alloy sheet.

Titanium Sheet Specimens 1" x 1" Squares	Brazing Foil, .003" Thick					
	Plain BT(1)		BT + 0.1% Li		BT + 0.5% Li	
	Short Run No.	Long Run No.	Short Run No.	Long Run No.	Short Run No.	Long Run No.
.023" Commercially Pure, MST III	2	3	4	5	6	7
.022" A-110AT	8	9	10	11	12	13
.020" 6 Al - 4V	14	15	16	17	18	19
.031" A-110AT (Ni plated, .0015" approx.)	24	25	-	-	26	27
.021" 6 Al - 4V " " " "	28	29	-	-	30	31
.015" 8 Mn " " " "	32	33	-	-	34	35

(1) BT is eutectic Ag-Cu alloy, 72% Ag-28% Cu, melting and flow point 1435°F manufactured by Handy & Harman. The BT with 0.1% and 0.5% Lithium additions were also supplied by Handy & Harman.

Short and long time heating runs were made on each combination listed above using the test method shown in Figure 1. The titanium core utilized was fabricated with commercially pure titanium foil, .002" x .500", formed and spotwelded by the Convair Fort Worth Division to produce 3/16" hexagonal cells. Four runs the same as No's. 8, 9, 24 and 25 were also made using stainless steel instead of titanium core.

PHASE I
MATERIALS AND TEST PROCEDURES, (Cont'd.)

The procedures for the short and long heating cycles were as follows:

Short Run

1. Heat to visual flow point in approximately 40 seconds.
2. Turn off the current immediately.
3. Specimen cools to below 800°F in approximately 20 seconds.
4. Turn off the argon and remove specimen when thermocouple records 350°F.

Long Run

1. Heat to visual flow point in approximately 40 seconds.
2. Continue to apply heat for 1 minute.
3. Turn off the current and allow to cool under flowing argon. The specimens cool to below 800F in approximately 30 seconds.

A typical time-temperature plot of heating and cooling cycle is given in Figure 2.

All core-skin specimens were sectioned, polished, etched and examined microscopically. Figures 3 and 4 are photomicrographs of cross sections through run No's. 28 and 29 respectively.

RESULTS AND INTERPRETATION OF PHASE I

1. Flows were satisfactory on all specimens. Lithium additions and nickel plating were apparently unnecessary. Since titanium begins to absorb its own oxide above 1300°F, the use of a flux or reducing gas is unnecessary. In fact, once the silver braze begins to flow excessive diffusion is the result if time above the flow temperature is not kept short. Of course, an inert gas or high vacuum must be used to prevent the formation of additional titanium oxides at the brazing temperature.

2. Microscopic examination of sectioned core-skin specimens showed a satisfactorily filleted bond could be formed with negligible core erosion using the short heating cycle.

3. Stainless steel core evidenced negligible alloying or erosion for both the short and long heating cycles. Flow and filleting were satisfactory.

PHASE II
MATERIALS, PROCEDURES AND RESULTS

The main intent of this phase was to develop a rapid heating and cooling fixture suitable for brazing a 4" x 8" titanium sandwich panel. Three principles of approach were employed - high frequency resistance, radiant and conductance heating.

PHASE II
MATERIALS, PROCEDURES AND RESULTS, (Cont'd.)

1. High Frequency Resistance Heating - A fixture was constructed in which high frequency current was passed through the titanium skin. Details of the method are reported in TN 56-254-1.

2. Radiant Heating - A fixture was constructed utilizing seven quartz heating lamps. It was attempted to control warpage by maintaining a gas pressure differential between the outside surface and the core-skin interface. Heating rate was satisfactory but warpage was excessive, even though apparently a 5 psi pressure differential was obtained. Because of the excessive warpage this method of heating was abandoned.

3. Conductance Heating - The skin face was heated by conductance of heat from a low mass electrically heated stainless steel strip. Warpage was controlled by pressure applied through low thermal conductivity fire brick. See Figure 5. An exploded view of the set-up is shown in Figure 6.

Preliminary tests on the larger size specimens indicated that plain .003" Easy Flo 45 foil wet and flowed as well as the BT foil. Consecquently, Easy Flo 45 was used in all additional specimens because of its lower flow temperature.

At first it was attempted to braze one face at a time. When the second face was brazed, however, the initially brazed core-skin interface was eroded excessively. Also oxidation was excessive around the periphery of the specimen, requiring the manifolding of argon gas. See Figure 6.

A specimen (Trial #12) which was considered of adequate quality for flexural testing was produced using the following procedure:

1. Pre-heat for 1 minute at 400 amps.
2. Increase amperage to 600 for 15 seconds. The core and skin became red hot but the filler metal did not flow around the periphery of the specimen. However, when 1/2" was trimmed from the sides it was found the filler had flowed well on both the top and bottom faces. Erosion of the core, as evaluated by visual examination, was slight.

This specimen was tested flexurally as shown in Figure 7, as recommended in Convair ZM-397. The results are graphed in Figure 8. Results from TN 8231 of a stainless steel sandwich panel are included for comparison.

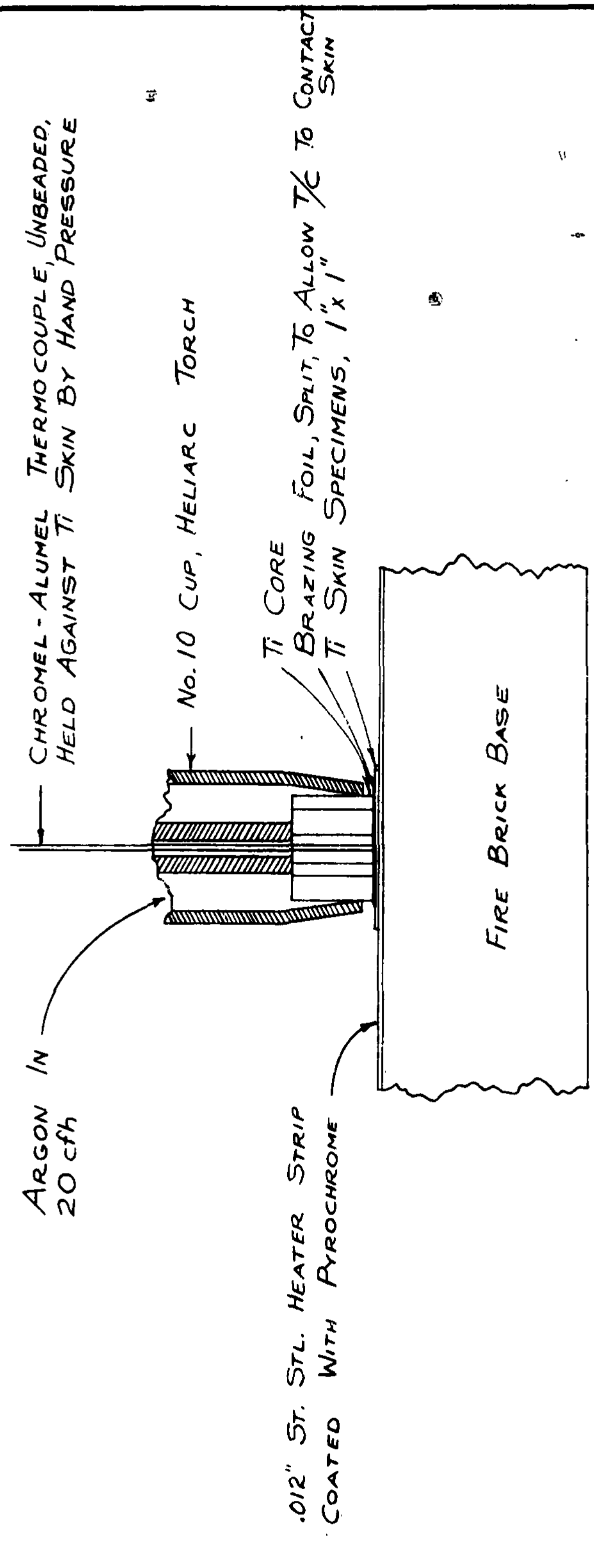


Figure 1 - Cross Section Of Test Set-Up Used To Evaluate Wetability
Of Core-Skin Specimens

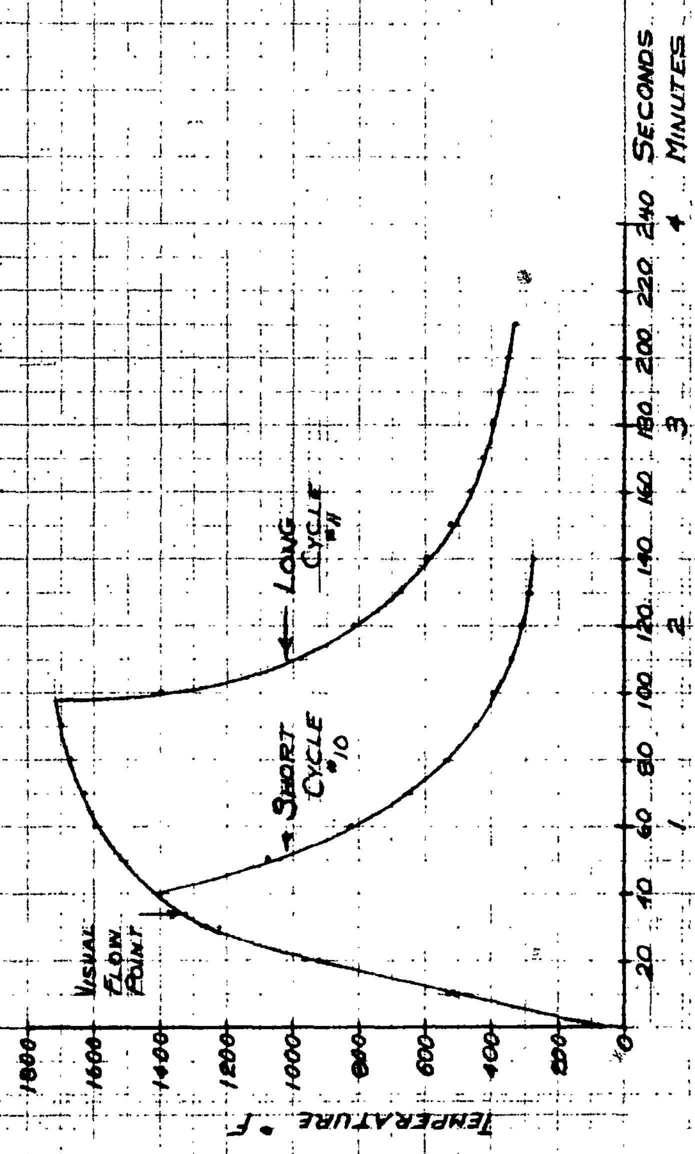
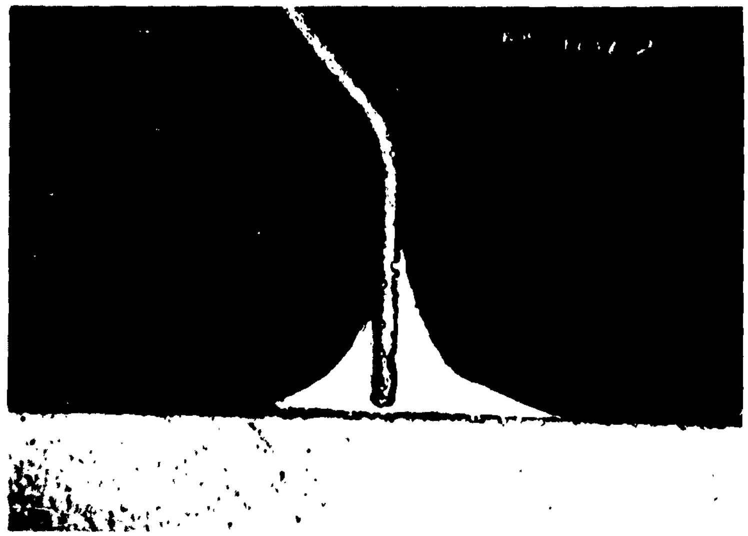
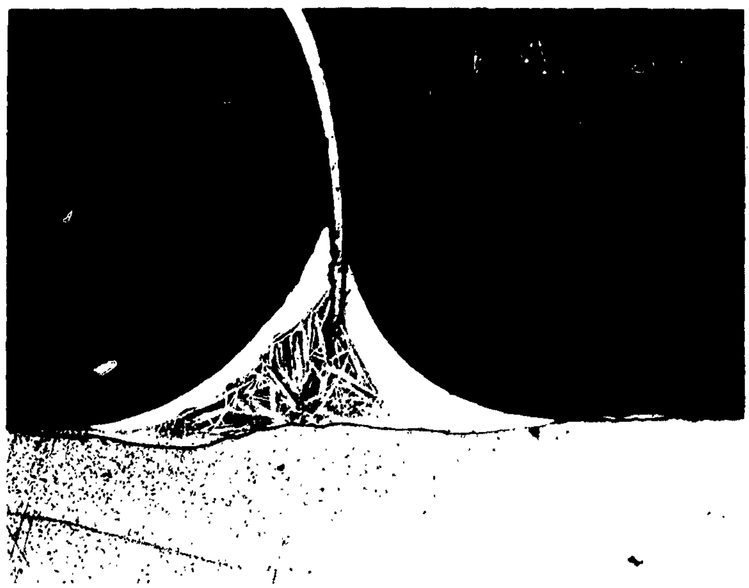


FIGURE 2 - TYPICAL TIME VS. TEMPERATURE PLOT OF A SHORT AND LONG HEATING CYCLE.



PM 1962 Figure 3 50X

Photomicrograph showing typical filleting obtained with a short heating cycle. Note small amount of diffusion and alloying of the brazing material (BT) with the core. Specimen No. 28.



PM 1963 Figure 4 50X

Photomicrograph showing typical joint obtained with a long heating cycle. Note considerable amount of diffusion and alloying of the brazing material with the core. Specimen No. 29.

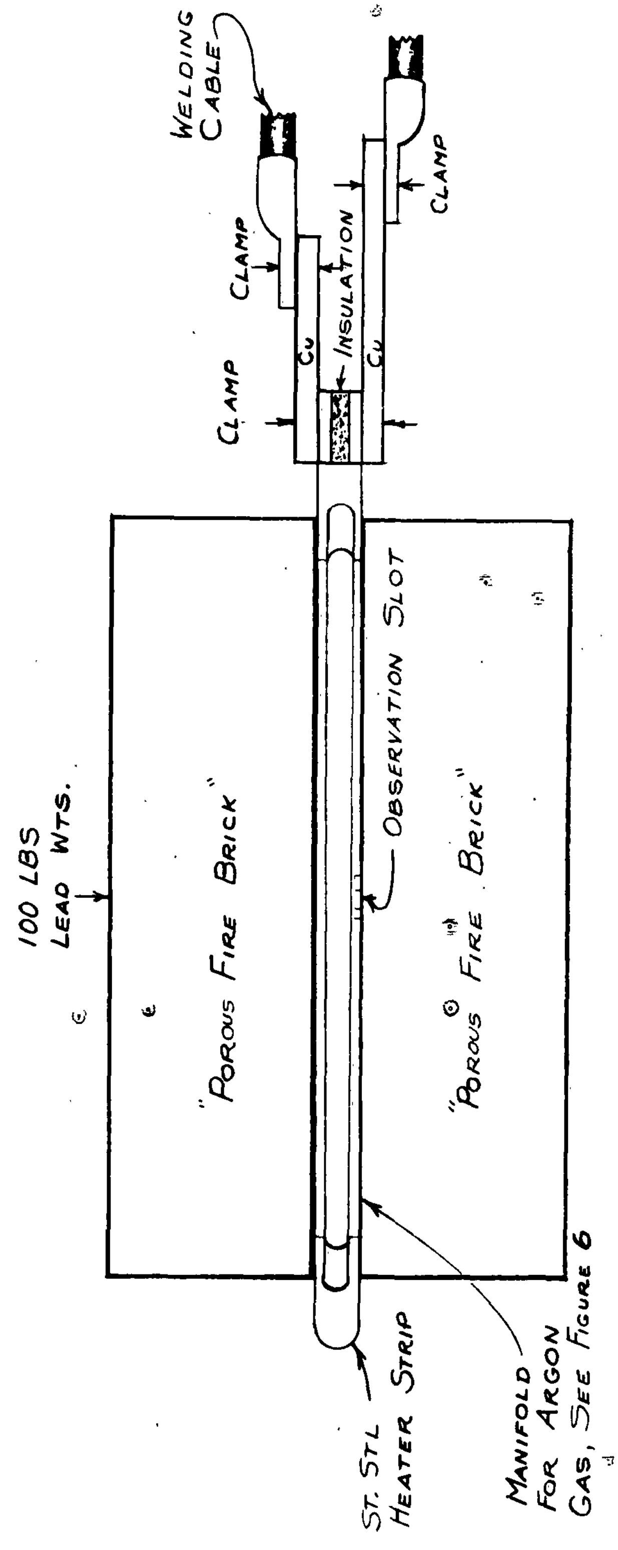
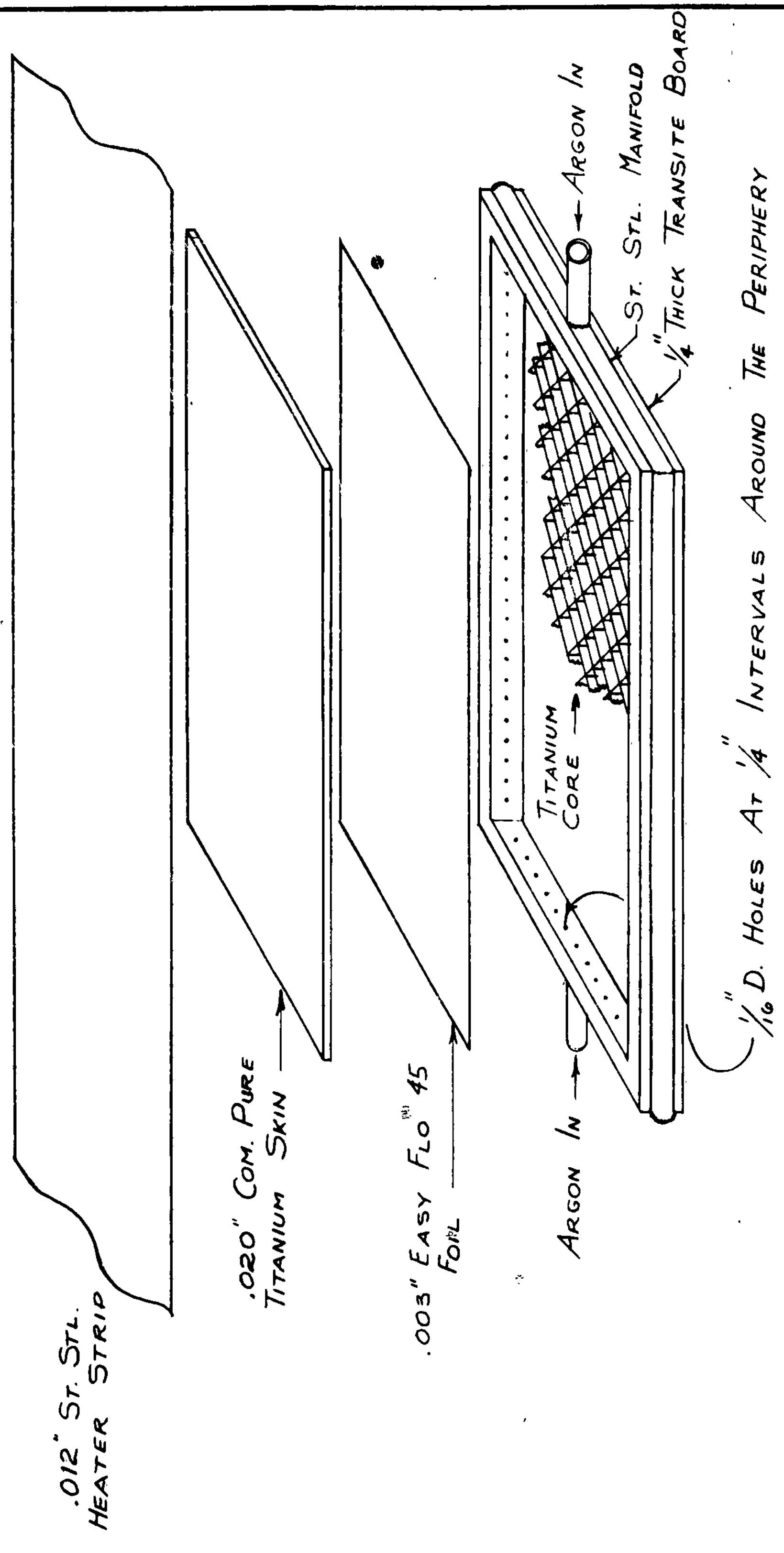
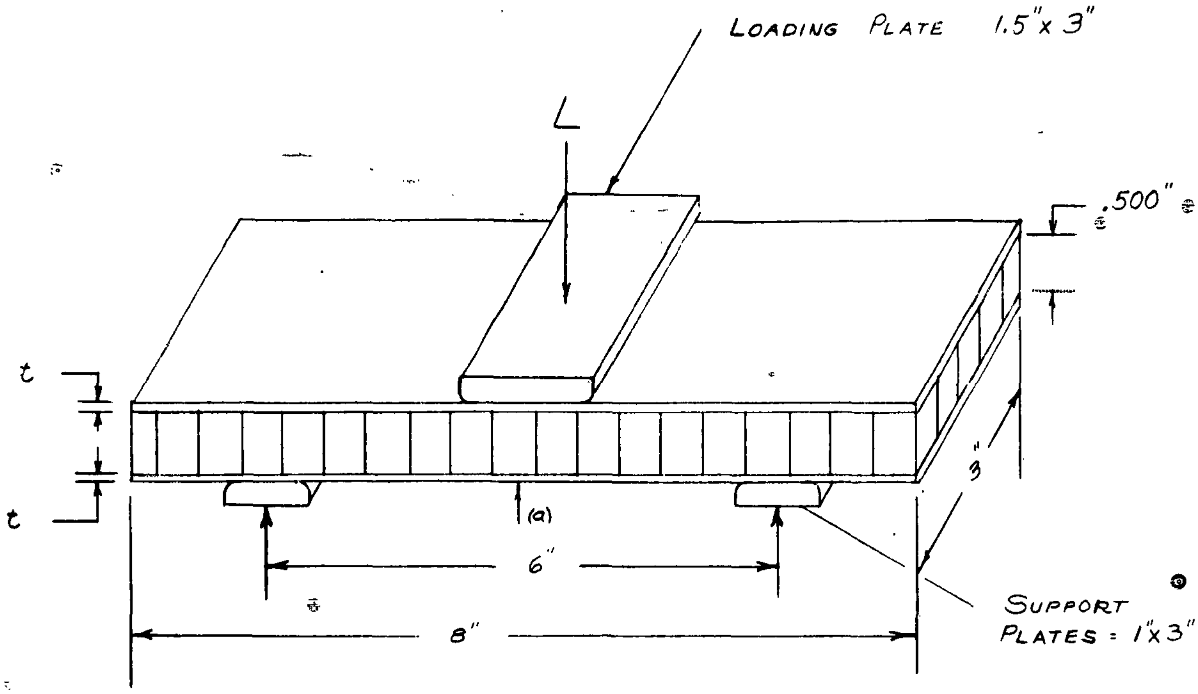


FIGURE 5-HEATING FIXTURE USED TO FABRICATE TITANIUM SANDWICH SPECIMEN



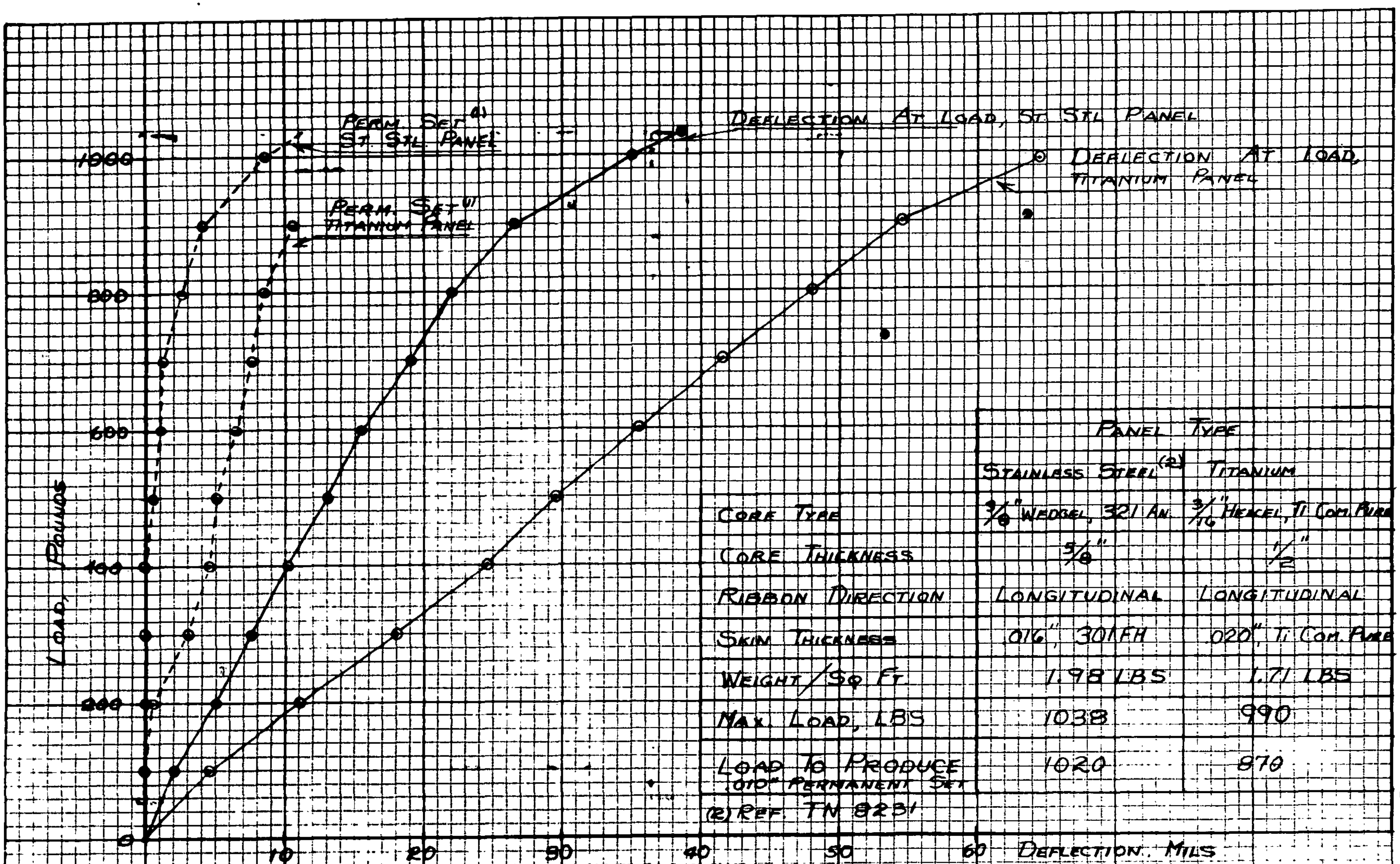
Sequence Of Foil, Skin And Heater Strip Is Repeated On The Bottom Side

Figure 6 - Exploded View Showing Juxtaposition Of Manifold, Core, Foil Skin And Heater Strip



(a) DEFLECTION MEASUREMENTS TAKEN MIDWAY BETWEEN SUPPORTS USING .001" FEDERAL DIAL GAGE

FIGURE 7 - SHEAR TEST FOR HONEYCOMB SPECIMEN PER ZM-397



	PANEL TYPE	
	STAINLESS STEEL (2)	TITANIUM
CORE TYPE	3/8" WEDGEL, 321 AN	3/16" HEXCEL, Ti COM. PURE
CORE THICKNESS	5/8"	1/2"
RIBBON DIRECTION	LONGITUDINAL	LONGITUDINAL
SKIN THICKNESS	.016", 301FH	.020", Ti COM. PURE
WEIGHT/SQ FT	1.98 LBS	1.71 LBS
MAX LOAD, LBS	1038	990
LOAD TO PRODUCE .010" PERMANENT SET	1020	870

(2) REF TN 8231

FIGURE 8 - LOAD VS. DEFLECTION AND PERMANENT SET OF A TITANIUM AND A STAINLESS STEEL SANDWICH PANEL TESTED ACCORDING TO ZM397 SEE FIGURE

(1) Permanent Set at 10 lbs tare load after loading to indicated ordinate load